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Production and Assessment of Red Alder Planting Stock

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Abstract

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A series of experiments was conducted over 4 years to test and develop methods to produce acceptable red alder planting stock and to assess quality and outplanting performance of resulting stock. Results indicated that red alder planting stock can be produced as containerized seedlings (plugs) or as bare-root nontransplant and transplant trees. In general, bare-root stock is larger and, hence, preferred over containerized trees, especially for planting on harsh sites or on any site where time considerations are important.

Keywords: Red alder planting stock, seedling characteristics, outplanting performance.

Summary

A series of experiments was conducted over 4 years, from 1987 through 1990, to (1) test and develop various methods to produce acceptable red alder planting stock, and (2) assess quality and outplanting performance of resulting stock. The tests were devised and carried out at different locations in western Washington by researchers and nurserymen from three cooperating organizations: the Pacific Northwest Research Station, Weyerhaeuser Company, and the Washington State Department of Natural Resources. Various sowing dates, seedling densities, and other cultural methods were tested. Containerized seedlings (plugs) and bare-root nontransplant and transplant trees were produced. Nontransplant stock was raised under bedhouse conditions and in open nursery beds. Transplants were started by sowing in the greenhouse and transplanting the young seedlings to open nursery beds. Characteristics of the different types of trees produced and their outplanting performance, under field conditions and with irrigation, were determined. Seedlings from the various experiments differed greatly in many of their growth characteristics. In general, the containerized trees were smallest, the bedhouse and openbed nontransplant trees were intermediate, and transplants were largest. The Webster nursery bedhouse trees, most of the openbed seedlings, and all transplants were highly vigorous, were well branched, and had large set buds. Such desirable characteristics enable the trees to better withstand animal damage and weed competition after planting. Roots of the unwrenched trees were compact, with a broomlike shape and many root tips; these trees may be easier to handle and plant in the field than nontransplants and wrenched transplants. Field survival with all stock ranged from 69 to 99 percent. Survival and growth of the transplants in the field were somewhat higher than the rest, especially after the first growing season. Field growth under irrigated conditions was spectacular; in two growing seasons, average height growth for the bare-root stock exceeded 350 cm. Clearly, such stock is preferable to containerized trees in establishment of red alder short-rotation, biomass-for-energy plantations. With all types of stock, different sizes of trees always can be obtained by making appropriate changes in the cultural methods used. Choice of type and size of planting stock depends on many factors, including condition of the planting site and plantation objective; for example, large transplant stock probably should be selected for harsh sites or for any site where time considerations are important.

Introduction

During the past decade, there has been a great increase in demand for red alder (*Alnus rubra* Bong.) products to produce energy and for various uses by the aluminum, furniture, and pulp industries. Plantations are being established, and demand for good red alder planting stock has increased. Yet, scientific information needed to produce quality stock is not available in the literature. Many forest tree nurseries in the Pacific Northwest produce superior conifer stock but have limited experience with alder. Previous efforts by various organizations in the region to produce good red alder stock have yielded mixed results. Some land managers resorted to use of wildlings to establish new plantations. Nutritional and other requirements for production of good red alder planting stock clearly are different from those of conifers.

We began a cooperative research effort to (1) test and develop various methods to produce acceptable red alder planting stock, and (2) assess quality and outplanting performance of resulting stock. This paper reports experiments conducted from 1987 through 1990 by researchers and nurserymen from three organizations: the Pacific Northwest Research Station, USDA Forest Service; Weyerhaeuser Company; and the Washington State Department of Natural Resources. A small part of the data recently was presented at a regional meeting (Radwan and Fangen 1990).

Experimental

Various experiments were conducted over 4 years by personnel from the three cooperating organizations at different locations in western Washington. Various sowing dates, seedling densities, and other cultural methods were tested. Containerized and bare-root nontransplants and transplant seedlings were produced. Outplanting performance of different stock types was evaluated at two clearcuts near Longview, Washington, and at an irrigated planting site near Yelm, Washington. Statistical assessment of most data was by calculation of standard error of the mean or by analysis of variance followed by Tukey's test (Snedecor 1961).

A selection of experiments representing the various tests conducted is detailed below. In these experiments, the customary English units are used for everything except seedling measurements, which are reported in the simpler metric units. For the reader's convenience, a table of English equivalents is given at the end of the text.

Styroblock-Container Experiment

The purpose of the experiment was to compare stock produced from seed sown on two different dates (June 1 and July 1, 1987), in each of two different sizes of styroblock containers (nos. 5 and 8). Each treatment was replicated four times, with a minimum of 60 seedlings per replication. Germination of the seedlot used was about 40 percent.

Styroblock cavities were filled with 1:1 (v/v) vermiculite/peat moss mixture inoculated with red alder endophytes from soil collected in a red alder stand. Seven to 10 seeds were sown in each cavity, and seeds were covered with a thin layer of silica grit to hold the seed down and to discourage algal growth. Styroblocks of the different treatments were placed at random on one bench in a greenhouse at the Forestry Sciences Laboratory in Olympia. Temperature in the greenhouse was about 70 °F during the day and 59 °F during the night. A bank of Growlux fluorescent lights supplemented natural light in early morning hours and extended the photoperiod in the evening to a total of 16 hours.[1] Water was added to the styroblocks as required during the first few weeks after sowing, and seedlings were gradually thinned to one seedling per cavity by the end of the fourth week. Seedlings were fertilized with full strength Hoagland solution (Hoagland and Arnon 1950) starting 3 weeks after sowing and at 2-week intervals thereafter during the following 4 weeks. To stimulate nitrogen fixation, Hoagland solution lacking nitrogen was then added to the seedlings at 2-week intervals for the next 4 to 8 weeks depending on the sowing date. Styroblocks were moved to a roofed lathhouse on September 1 to allow the trees to harden off gradually. By the end of September, addition of nutrient solution was discontinued to slow height growth and to encourage budset and cold hardiness. After leaffall in January, 10 representative seedlings of each replication in each treatment were measured for height, diameter, and shoot and root dry weights. Also, 25 representative seedlings of each replication in each treatment were selected for a field-performance test in 1988. These seedlings were stored in a cooler (ca. 35 °F) until outplanted in March 1988.

Results and discussion—The data show that seedling quality differed by treatment (table 1). In general, seedling size differed in the following order: June sowing in large cavities > June sowing in small cavities = July sowing in large cavities > July sowing in small cavities. Roots of all seedlings were variously nodulated and were much smaller than shoots in all treatments, especially with late sowing in small cavities. Seedlings from the best treatment were still very small relative to seedlings obtained with other cultural methods described below. Seedlings in nos. 5 and 8 containers are shown in figure 1. Outplanting performance of the seedlings is discussed later in the text.

Bedhouse Experiments

Wind River Nursery trials—From 1987 to 1989, the USDA Forest Service Wind River Nursery, near Carson, Washington, grew red alder planting stock for Weyerhaeuser Company. Seed was sown in April in a bedhouse enclosed with plastic cover. Soil was fertilized before sowing, and the beds were watered and weeded as required. Seedlings were harvested the following March for outplanting.

Results and discussion—Few data were collected. The brief data in table 2 show that seedlings were tall and spindly; they were heavier than the containerized seedlings, but they did not look vigorous. The seedlings also had few branches.

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[1] The use of trade or firm names is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Table 1—Growth characteristics of containerized red alder seedlings at lifting in January 1988[a] [b]

Sowing date and cavity size	Height	Diameter	Shoot dry weight	Root dry weight	Shoot-to-root ratio
	cm	*mm*	----- *Grams*	-----	
6-1-87; large	34.0 a	2.9 a	0.48 a	0.32 a	1.50 a
6-1-87; small	26.4 b	2.3 a	.27 b	.20 b	1.35 a
7-1-87; large	26.0 b	2.6 a	.30 b	.16 b	1.88 b
7-1-87; small	22.4 c	2.2 a	.19 c	.10 c	1.90 b

[a] Seedlings were grown at the Forestry Sciences Laboratory, Olympia, Washington.
[b] Values are averages of 40 seedlings each (10 seedlings by 4 replications). Large styroblock cavity (no. 8) = 131 cm^3, small styroblock (no. 5) = 82 cm^3. Values in the same column followed by the same letter are not significantly different at $p < 0.05$, based on Tukey's test.

Figure 1—Containerized seedlings in September 1987 from the June 1 sowing. Larger size styroblock (right) produced larger seedlings.

Webster State Forest Nursery experiment—At the Webster nursery in Olympia, Washington, a bedhouse covering an area of 400 ft^2 was constructed from 1/2-inch plastic pipe and 6-mil plastic sheeting. Prior to the frame being erected, the area was rototilled and fertilized with a 10-20-20 fertilizer at 200 lb/acre, a 0-45-0 fertilizer at 200 lb/acre, and Dolomite at 2,000 lb/acre. The soil was fumigated with methyl bromide 10 days before sowing occurred.

Seed (72 percent germination) was sown on two different dates—March 1 and April 1, 1988. On each date, seed was sown in each of 64 furrows, 1/4 inch deep and 2 inches apart. Furrows were about 2 feet long with 60 seeds sown in each one. Seed was covered with a thin layer of silica grit, and the beds were watered with a slurry of crushed-nodule inoculum containing red alder endophytes. One month after sowing, seedlings were fertilized at weekly intervals with a dilute solution of 20-20-20 fertilizer. The plastic sheeting was removed from the frame on June 1. The beds were watered and weeded as required during the growing season. Seedlings were lifted in January 1989. At harvest, 20 seedlings were taken at random from each treatment to determine average seedling size.

Table 2—Growth characteristics of the bedhouse seedlings produced at the Wind River Nursery in 1987 (n = 53)

Characteristic	Measure
Seedling height	67.0±3.0 cm[a]
Seedling diameter	5.6±0.3 mm[a]
Shoot dry weight	4.0 g
Root dry weight	2.0 g

[a] Value is followed by the standard error of the mean (SE).

Table 3—Growth characteristics of the bedhouse red alder seedlings grown at Webster State Forest Nursery at lifting in January 1989[a]

Sowing date	Seedling height	Seedling diameter	Shoot dry weight	Root dry weight	Seedling dry weight	Shoot-to-root ratio
	cm	*mm*		*Grams*		
3-1-88	59.6±0.4	7.5±0.1	5.9±0.3	4.1±0.3	10.0±0.6	1.44±0.1
4-1-88	40.2±2.6	6.4±0.4	3.0±0.4	2.6±0.4	5.6±0.8	1.15±0.1

[a] Values, ± SE, are averages of 20 seedlings each.

Results and discussion—Seed sown on March 1 did not germinate until March 18 because the outside temperature was abnormally low during the first part of March. Seed sown April 1 germinated after about 7 days. Initial seedling growth was slow, but it accelerated with the warm weather. Red alder seedlings typically do not grow much when air temperature is below 65 °F.

At lifting, seedlings from the March sowing were taller and heavier than those from the April sowing (table 3). All seedlings appeared sturdy and healthy and roots were nodulated. Seedlings were much larger than the plug trees produced in the earlier styroblock-container experiment; even the smallest bedhouse trees from the April sowing were seven times heavier than the best plug trees. The seedlings were shorter but much sturdier and heavier (1.7 times) than the bedhouse trees produced earlier at the Wind River Nursery. The culture methods used to produce the bedhouse trees at each of the two nurseries were very different. Figure 2 shows the Webster bedhouse trees in September 1988.

Openbed Experiments

Several experiments were conducted where seed was sown directly in open nursery beds. The first experiment was carried out at Weyerhaeuser's Mima nursery in 1987. Other trials followed at both the Mima and the Webster nurseries. Following are details of two experiments, one at Mima and one at Webster.

The Mima nursery experiment—The experiment was designed to test the feasibility of producing good red alder stock in open nursery beds. The experiment also was designed to compare stock from two sowing dates (May 1 and June 1, 1987) at each

Table 4—Growth characteristics of the Mima nursery, openbed red alder seedlings at lifting in January 1988[a] [b]

Sowing date and density	Seedling height	Seedling diameter	Shoot dry weight	Root dry weight	Seedling dry weight	Shoot-to-root ratio
	cm	*mm*		*Grams*		
5-1-87; high	30.0±4.8	3.2±0.3	1.37±0.34	0.90±0.16	2.27±0.48	1.52±0.20
5-1-87; low	31.0±1.0	4.1±0.3	1.93±0.36	1.57±0.35	3.50±0.70	1.23±0.10
6-1-87; high	14.0±1.9	2.8±0.3	.51±0.14	.87±0.20	1.38±0.34	.59±0.02
6-1-87; low	11.0±2.1	2.7±0.8	.43±0.17	.79±0.32	1.22±0.49	.54±0.02

[a] High density = about 25 seedlings/ft^2; low density = about 10 seedlings/ft^2.
[b] Values, ± SE, are averages of 200 seedlings each.

Figure 2—Bedhouse red alder seedlings in September 1988. Seeds were sown in March 1988 at Webster State Forest Nursery. Plastic cover was removed in June 1988.

of two seedling densities (10 and 25 trees per ft^2). Each of the four treatments was replicated four times. Each replication covered 5 lineal feet of nursery-bed space, and replications were separated by about 3 feet of unsown bed space. Seedbed soil was treated with triple superphosphate at 1,500 lb/acre. Seed was sown by hand, and sown seed was covered with Reemay polyester sheets that were removed after about 1 month when newly emerged seedlings were about 1 cm tall. The beds were watered and weeded during the growing season as required. Following leaffall in January, representative seedlings were taken to determine seedling size and for use in a field-performance test.

Results and discussion—All trees were healthy and vigorous; they were smaller (table 4) than the bedhouse trees grown at Webster nursery (see table 3) but much heavier than the plug trees (see table 1). The trees also were much shorter than the spindly bedhouse trees grown at Wind River (see table 2).

Figure 3—Red alder openbed seedlings in September 1988 from the May 1 sowing at Mima nursery.

The largest trees were those grown from seed sown at low density, early in May; the seedlings had more time and space for growth. Shoot-to-root ratios were more than one for early sowing and much less than one for late sowing. As with the plug trees, late sowing did not give the trees enough time to form a good root system and a balanced seedling. Figure 3 shows the May seedlings in September 1988. Outplanting performance of the trees is discussed later.

The Webster nursery test—This test was conducted in 1989. Seed (72 percent germination) was sown by machine in early April. Seedbeds were fertilized and inoculated with red alder endophytes before sowing to give about 25 seedlings per ft^2. Fertilizers applied were 10-20-20 at 100 lb/acre, 0-45-0 at 200 lb/acre, and Dolomite at 2,000 lb/acre. Seed was covered with silica grit and the beds were covered with Reemay fabric sheets that kept the beds warm and allowed some light and water to go through. Germination started in mid-May, and the Reemay sheets were removed June 1, 1989. The beds were watered, weeded, and fertilized as needed during the growing season. Seedlings were harvested in January 1990. Twenty representative trees were selected at random to determine growth characteristics, and a subsample of five trees was used to determine number of branches per tree and average branch length.

Results and discussion—Roots of all seedlings were nodulated, and seedlings appeared healthy and vigorous. Tree height, diameter, and shoot-to-root ratio (table 5) were similar to the bedhouse trees produced earlier at Webster nursery (table 3). The trees, however, were much larger than the containerized seedlings (table 1) and the openbed trees produced in 1987-88 at the Mima nursery (table 4). Average number of branches per seedling (4.0) and average branch length (4.9 cm) were adequate but lower than those of the transplant trees produced in the greenhouse-openbed experiment outlined below. Still, the trees appeared sturdy, well branched, and large enough to withstand animal damage and weed competition when outplanted in the field.

Table 5—Growth characteristics of the Webster nursery, openbed red alder seedlings at lifting in January 1990[a]

Characteristic	Measure
Seedling height	53.8±2.9 cm
Seedling diameter	7.6±0.3 mm
Seedling dry weight	10.2±1.2 cm
Shoot-to-root ratio	1.3±0.1
Branches per seedling	4.0±1.0
Branch length	8.2±1.0 cm

[a] Values, ± SE, are averages of 20 seedlings for height, diameter, dry weight, and shoot-to-root ratio, and 5 seedlings each for branches per seedling and branch length.

Greenhouse-Openbed Experiments

The greenhouse-openbed experiments were based on an old idea long used in agriculture and horticulture. Trees were started by sowing early in March or April in the greenhouse. The young trees were transplanted to open nursery beds in early summer. Large stock trees were harvested at the end of the growing season. We refer to these trees as "transplant" stock (also "plug + 1/2" or "plug transplants"). By comparison, all trees produced in earlier experiments are termed "nontransplant" stock because production did not include transplanting.

Three experiments were conducted to produce transplant stock. The first two experiments were carried out in 1988 and 1989 at the Webster nursery. The third experiment was run in 1989 at the Mima nursery. All three experiments are similar in most respects. Only one experiment is detailed below.

The 1989 experiment at Webster nursery—Seed (72 percent germination) was sown in no. 2A (240 cavities/block) and no. 4A (200 cavities/block) styroblocks on April 1, 1989. The cavities were filled with 1:1 (v/v) vermiculite/peat moss mixture inoculated with red alder endophytes. Three seeds were sown per cavity, and seeds were covered with silica grit. Blocks were kept in a greenhouse maintained at a day-night temperature regime of 80 and 70 °F for germination and 70 and 60 °F after seedlings began to emerge in 2 weeks. The blocks were watered and fertilized as needed, and seedlings were thinned to one per cavity 5 weeks after sowing.

The blocks were moved out of the greenhouse to a sheltered lathhouse on June 1. Seedlings were allowed to harden off in the lathhouse until June 12 when they were outplanted in an open nursery bed. The bed had been fertilized with 10-20-20 fertilizer at 100 lb/acre, 0-45-0 fertilizer at 200 lb/acre, and Dolomite at 2,000 lb/acre. Seedlings were planted by machine at a spacing of 10 inches between rows and 4 inches within rows (that is, 3-4 seedlings/ft^2). Seedlings were watered and weeded as required during the growing season. Because the trees were growing too fast, half the seedlings of each treatment were wrenched in August 1989 by passing a blade under the roots at a depth of 10 inches.

Seedlings were lifted in January 1990, and 20 representative trees of each treatment were taken at random to determine seedling height, diameter, and dry weight. A subsample of five trees also was used to determine number of branches per tree and average branch length.

Figure 4—Openbed nontransplant (left) and transplant (right) red alder stock at Webster nursery near the end of the 1989 growing season.

Results and discussion—The transplant stock appeared to be better than any other red alder trees produced in any of the earlier experiments. The trees were large and sturdy. Branches were numerous, roots were nodulated, and set buds were large and healthy. Figure 4 shows the difference between transplant and nontransplant stock near the end of the 1989 growing season.

Roots of the unwrenched trees appeared more compact than those of wrenched, transplant stock or the nontransplant, bare-root seedlings produced in other experiments. The unwrenched root systems had a broomlike appearance with many root tips; the trees may be easier to handle and plant in the field. Apparently, the desirable characteristics of the unwrenched roots resulted from starting the seedlings in styroblocks. In the beginning, the small size and shape of the styroblock cavities limited the horizontal spread of the roots and forced them downward. When the resulting plugs were transplanted to the nursery beds, the roots continued their downward elongation with relatively uniform horizontal spreading along the entire root system, through formation of fine root branches and new roots, and hence more root tips. Wrenching changed the shape of the roots. Roots of the wrenched trees were generally wider and more irregular in shape than roots of the unwrenched trees.

Some quantitative measures of seedling morphology are shown in table 6. Growth characteristics differed by treatment. In general, transplants started in no. 4A styroblocks were somewhat larger and heavier than those started in no. 2A styroblocks. Other differences between the two types of stock, however, were minor. Starting transplants in no. 2A styroblocks, which have more cavities per block, would produce lower cost stock.

Wrenching reduced seedling height, diameter, dry weight, shoot-to-root ratio, and number and length of branches. The fewer branches per tree and the shorter branch length of the wrenched trees are apparent disadvantages. Branches are desirable because they tend to enable the trees to better withstand animal damage and weed competition after planting.

Table 6—Growth characteristics of Webster nursery red alder transplant stock at lifting in January 1990[a]

Styroblock size and wrenching treatment	Seedling height	Seedling diameter	Seedling ovendry weight	Shoot-to-root ratio	Branches per seedling	Branch length
	cm	*mm*	*Grams*			*cm*
2A; unwrenched	84.2 a	9.4 a	25.5 a	1.6 a	9 a	12.9 a
2A; wrenched	70.9 b	8.7 a	21.5 a	1.1 a	6 b	7.6 b
4A; unwrenched	85.3 a	9.8 a	26.4 a	1.6 a	8 a	13.0 a
4A; wrenched	71.1 b	9.8 a	25.7 a	1.1 a	7 a	7.0 b
Average	77.9	9.4	24.8	1.4	8	10.1

[a] Styroblock cavities: 2A = 38 cm^3, 4A = 59 cm^3. Values are averages of 20 seedlings each for height, diameter, dry weight, and shoot-to-root ratio, and 5 seedlings each for branches per seedling and branch length. Values in the same column followed by the same letter are not significantly different at $p < 0.05$, based on Tukey's test.

Evaluation of Outplanting Performance

Three tests were conducted to assess the outplanting performance of red alder stock. Two experiments were conducted on a clearcut under normal field conditions and a third experiment was run on a former pasture site provided with drip irrigation. The experiments were installed in 1988 and 1989.

The 1988 field test—The outplanting site is on Weyerhaeuser land, about 10 miles east of Longview, Washington. The site is in the Washington Coast Range at an elevation of 840 feet. The soil is Germany series, and site index (Douglas-fir) at 50 years is 140 feet (II+). The site was broadcast burned and treated with preplant herbicides. The containerized (Forestry Sciences Laboratory, Olympia) as well as the openbed (Mima nursery) and bedhouse (Wind River Nursery) trees produced in the 1987-88 experiments described above were used. Experimental design was randomized block. There were four blocks and in each block different types of stock were represented by 25 trees, each planted at approximately 6- by 6-foot spacing. Trees were assessed for survival and growth at the end of the first and second growing seasons.

Results and discussion—Growth and survival differed among the types of stock used (table 7). In general, the openbed stock from the early sowing showed the best performance; the trees were the most vigorous at planting. Worst survival was by the small-cavity, July-sown, containerized stock and by the bedhouse seedlings from Wind River Nursery. Openbed stock and plugs from early sowings performed better than those from late sowings. Similarly, plugs from large styroblock cavities grew and survived better than those from small styroblock cavities. Clearly, the larger and more vigorous the stock, the better was its field performance. The best stock available, therefore, should always be favored when plantations are established, provided the cost is acceptable.

Table 7—Growth and survival of red alder stock outplanted March 1988 at a cutover site near Longview, Washington[a]

Stock type and sowing date and styroblock cavity size or density in nursery bed	Height at planting	Height growth: 1 year	Height growth: 2 years	Survival
	Centimeters	*Centimeters*	*Centimeters*	*Percent*
Containerized stock (Forestry Sciences Laboratory, Olympia):				
6-1-87; small cavity	24±1	36±1	167±13	77±2
6-1-87; large cavity	29±2	40±2	174±13	78±4
7-1-87; small cavity	17±1	33±2	149±14	69±10
7-1-87; large cavity	21±1	37±2	163±15	82±3
Openbed stock (Mima):				
5-1-87; high density	46±4	65±6	221±17	88±3
5-1-87; low density	42±4	63±4	227±8	94±2
6-1-87; high density	16±3	59±4	207±15	89±6
6-1-87; low density	10±1	49±7	193±16	84±6
Bedhouse stock (Wind River):				
3-1-87	52±3	41±4	173±13	69±4

[a] Small cavity = no. 5 styroblock; large cavity = no. 8 styroblock. High density = 25 seedlings/ft^2; low density = 10 seedlings/ft^2; percentage survival for end of 2d year. All values ± SE.

The 1989 field test—The 1989 field test was established on a site different from that used in the 1988 field test. The site is on Weyerhaeuser land, about 10 miles east of Longview, Washington, in the foothills of the Cascade Range at 700 feet elevation. The soil is Dunnigan series with a Douglas-fir site index of 130 feet at 50 years. Site preparation consisted of scarification and pile-burn and application of preplant herbicides. Red alder stock evaluated included transplants from Webster nursery; openbed, nontransplant trees and supercell plugs from the Mima nursery; and bedhouse, nontransplant trees from Wind River Nursery. All trees were grown in 1988 and outplanted for assessment of field performance in April 1989. Planting was in a randomized block design, at 6- by 6-foot spacing. There were four replications and 25 trees of each stock type in each replication. Trees were assessed for growth and survival at the end of the first and second growing seasons.

Table 8—Growth and survival of red alder stock outplanted in 1989 at a cutover site near Longview, Washington[a]

Planting stock	Initial height	Height growth		Survival
		1 year	2 years	
	Centimeters			*Percent*
Transplant A	64 b	84 a	211 ab	99 a
Transplant B	56 b	89 a	220 a	96 a
Transplant C	31 d	81 a	208 ab	98 a
Supercell plug	37 cd	42 bc	169 bc	94 a
Openbed nontransplant	42 c	59 b	192 ab	92 a
Bedhouse nontransplant	98 a	35 c	139 c	89 a

[a] A-C are different types of transplants grown at Webster nursery, supercell and openbed stock grown at Mima nursery, bedhouse trees from Wind River Nursery, supercell cavity = 164 cm^3. Percentage survival for end of 2d year. Values in the same column followed by the same letter are not significantly different at $p < 0.05$, based on Tukey's test.

Results and discussion—Initial seedling height was greatest for the bedhouse trees, intermediate for transplants A and B, openbed nontransplants, and supercell plugs, and lowest for transplant C (table 8). The tallest seedlings, however, were the least vigorous; they lacked the well-developed buds and ample branching characteristics of the openbed and transplant stock. Height growth of the transplants was greatest among all stock types at the end of the first and second growing seasons. At the end of the first growing season, the average gains in height by the transplants were 102 and 81 percent higher than those by the supercell-plug trees and the other nontransplant stock, respectively. Differences among stock types in height growth were smaller at the end of the second growing season. Still, the transplant trees maintained their superiority in height growth over other stock types.

Seedling survival was excellent for all stock. Survival for transplants was somewhat higher than for the rest; thus, it may be prudent to use the transplant stock on harsh sites.

The 1989 irrigated field test—The test site for the irrigated field test is near Yelm, Washington, 160 feet elevation. It is part of a fenced seed orchard established by the Washington State Department of Natural Resources. Soil is Nisqually loamy sand and site index (Douglas-fir) is 120 feet. Red alder stock tested included transplants and nontransplants grown at Webster nursery in 1988. The site was rototilled and connected to a drip irrigation system before planting. Trees were outplanted in April 1989 at 3- by 3-foot spacing. Trees were irrigated and weeded as required. Tree heights were measured at the end of the first and second growing seasons.

Table 9—Initial height and height growth of transplant and nontransplant red alder stock outplanted in 1989 at an irrigated site near Yelm, Washington[a]

Planting stock	Initial height	Height growth	
		1 year	2 years
	----- *Centimeters* -----		
Transplant A	70±4	188±6	380±7
Transplant B	60±5	193±5	370±13
Transplant C	32±2	178±7	361±11
Transplant D	81±5	205±9	385±20
Openbed nontransplant A	52±4	147±7	349±8
Openbed nontransplant B	32±2	151±6	349±13

[a] All seedlings were grown at Webster nursery. Letters A-D indicate different methods of stock production. Transplants A-C are same types as those used in the 1989 field test. Values, ± SE, are averages of 20 trees each.

Figure 5—Red alder trees at the irrigated site near Yelm at the end of two growing seasons from planting. Trees were planted in spring 1989 with transplant and nontransplant stock.

Results and discussion—Initial height of the trees differed by stock type (table 9). In general, transplants were taller than nontransplants. After planting, seedlings grew very rapidly. By the end of the first growing season, height growth ranged from 150 to 214 cm. More growth was added during the second year (fig. 5). In two growing seasons, average height growth was 382 and 344 cm for transplant and nontransplant trees, respectively. By comparison, red alder plugs previously planted on the same site grew only an average of 250 cm in 2 years. The bare-root stock used in this experiment, especially the transplants, would be preferable to containerized stock in the establishment of new red alder short-rotation, biomass-for-energy plantations.

Conclusions and Recommendations

It is clear from the experiments reported here that red alder planting stock can be produced as containerized seedlings (plugs) and as bare-root trees. Containerized seedlings can be raised in containers of many shapes and sizes. The bare-root stock, on the other hand, can be produced as nontransplant or transplant trees.

Containerized seedlings have some advantages, including low production and outplanting costs; however, red alder plugs are usually not as good as bare-root stock. Only bare-root methods can produce the large, sturdy stock, with vigorous branches, well-developed buds, and balanced shoot-to-root ratio required for successful field planting, especially on harsh sites.

Of the different types of bare-root stock tested here, we prefer the transplants and openbed nontransplants. Quality transplants (plug + 1/2) may be started in no. 2A styroblocks, and the young seedlings are transplanted in nursery beds at 4- by 10-inch spacing. The more economical nontransplants also should be grown at about six seedlings per ft^2. In 1990, demand for transplants increased, and some 500,000 trees were produced commercially at the Mima and Webster nurseries by using the methods outlined above.

With all types of stock, different sizes of trees always can be obtained by making appropriate changes in the cultural methods used, such as date of sowing, spacing, styroblock size, root wrenching, and irrigation and fertilization regimes. Inoculation with red alder endophytes and fertilization, especially with lime and phosphorus, always will be essential to production of quality stock.

Choice of type and size of planting stock depends on many factors, including funds available, plantation objectives, and condition of the planting site. Based on available field data and current cost estimates to produce different kinds of stock, bare-root, nontransplant stock (1+0) should be the clear choice for most red alder sites. Large transplant stock probably should be selected for harsh sites or for any site where time considerations are important.

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English Equivalents

1 millimeter (mm) = 0.039 inch (in)
1 centimeter (cm) = 0.39 inch (in)
1 cubic centimeter (cm^3) = 0.06 cubic inch (in^3)
1 gram (g) = 0.03527 ounce (oz)
1 degree C (^oC) = (^oF-32)/1.8
1 square meter (m^2) = 10.8 square feet (ft^2)

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A series of experiments was conducted over 4 years to test and develop methods to produce acceptable red alder planting stock and to assess quality and outplanting performance of resulting stock. Results indicated that red alder planting stock can be produced as containerized seedlings (plugs) or as bare-root nontransplant and transplant trees. In general, bare-root stock is larger and, hence, preferred over containerized trees, especially for planting on harsh sites or on any site where time considerations are important.

Keywords: Red alder planting stock, seedling characteristics, outplanting performance.

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